General Application Name: Public Works/Service Authority

Product / Service / Function Name: Storm Water Management Program

P/S/F Description:

A storm water management program (SWMP) encompasses many aspects of administering a storm water drainage system, addressing both the quantity and quality of the storm water runoff. A SWMP is designed to evaluate the effectiveness of current storm water management policies and practices and support recommendations for future changes in those practices. SWMPs are used for master planning as well as predicting environmental impacts on watersheds and floodplains. This type of program should also handle any work order requests as well as prioritize maintenance in general. A SWMP can also aid in budgeting for repairs and new infrastructure.

A SWMP should be designed to respond to citizen reports of flooding or leaking and provide an up-to-date inventory of the storm water infrastructure to meet the requirements the Governmental Accounting Standards Board Statements Number 34: Basic Financial Statements (GASB 34). GASB 34 redefines the accounting standards for state and local governments. Organizations must either calculate the historic cost of each asset minus its depreciation through time, or develop an infrastructure asset inventory and management system that will generate an accurate inventory of all assets, report the condition of assets every three years, and determine the annual estimate of the cost needed to maintain the asset in its current conditions. Because of its unique ability to relate individual components and their attributes to specific locations, GIS is well suited for creating and maintaining detailed, auditable infrastructure inventories.

A SWMP can also be used to help meet the requirements for the NPDES (National Pollutant Discharge Elimination System) program permitting. The main goal of a SWMP is to be proactive rather than reactive in terms of predicting and preventing potential future infrastructure problems.

Product / Service / Function

1. Spatial Data -

   Minimum Data Requirements

General Description	GIS Data Layer
Storm Water Data	Channels
	Culverts
	Pipes
	Manholes/Junction Boxes
	Pipe Inlet/Outlet
	Catch Basins
	Inlets
	Bridges
	Spillways
	Swales
Natural Features	Streams
	Lakes
Transportation	Right-of-way and/or edge of pavement

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	Road centerlines
Socio-Political Data	Municipal boundaries
	Land Use
Other	Datasets required for hydrologic modeling

Optional Data Requirements

General Description	GIS Data Layer
Storm Water Data	Pipe cross-sections
Planimetrics/Base Mapping	Orthophotography
	Zoning
Natural Features	Vegetation
	Flood zones
	Digital Terrain Model (DTM or DEM)
	Contours (1 or 2 feet)
Transportation	Railroads
	Driveways
	Parking Lots
Socio-Political Data	Neighborhoods & Subdivisions
Other	Datasets required for hydrologic modeling

2. Attribute Data –

Minimum Attribute Requirements

GIS Data Layer	Attributes
Channels	Feature ID
	Manning's Roughness Coefficient
	Right/Left overbank slope
	Channel geometry
	Up invert elevation
	Depth of channel
	Top width of channel
	Bottom width of channel
	Upstream feature ID
	Downstream feature ID
	Inspection Date
Culverts/Pipes	Feature ID
	Height
	Width
	Shape
	Material
	Rim Elevation
	Inspection Date
	Direction of Flow

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Manholes/Junction Boxes	Feature ID
	Depth
	Radius/size
	Rim Elevation
	Inspection Date
Pipe Inlet/Outlet	Feature ID
	Elevation
Catch Basins	Feature ID
	Depth
	Radius/Size
Inlets	Feature ID
	Overall Condition
	Grate Condition
	Material
	Inspection Date
Bridges	Feature ID
	Road Name
Spillways	Feature ID
	Description
	Size
Swales	Feature ID
	Description

*Optional Attribute Requirements**

GIS Data Layer	**Attributes**
Channels	Condition
	Flow (high, low, etc.)
	Water Color
	Odor
Culverts/Pipes	Upstream Invert Elevation
	Downstream Invert Elevation
	Condition
	Flow (high, low, etc.)
	Water Color
	Odor
Manholes/Junction Boxes	Condition of Structure
	Private Tie Ins
	Material
	Surrounding Condition
	Steps
	Stilling Basin
Pipe Inlet/Outlet	Evidence of Scour
	I/O Configuration (mitered, flared, etc.)
	Percent Obstructed
Catch Basins	Condition/Description
Inlets	No. of Private Tie Ins

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	Steps (Y/N)
	Surrounding Condition

*Other attributes may be required depending on the type of hydrologic modeling that will be done.

3. Data Acquisition Options (integrated with VBMP digital orthos)

   Before any SWMP can be fully developed, a storm water drainage inventory should be taken. This is critical so that the SWMP best reflects the infrastructure and its behavior. Please see the VBMP Reference Book topic on Storm Water Drainage Inventory for a discussion on data acquisition for this infrastructure.

   The GIS data layers created from the inventory can be used to calculate input for several types of hydrologic models. More can be learned about the different types of models and their data requirements from the Hydrologic Engineering Center of the US Army Corps of Engineers. <www.hec.usace.army.mil.> Hydrologic models are also important in the development of a useful SWMP. Without running models, there is no way to predict future behaviors of the drainage system by conducting "what if" scenarios. Predicting future behaviors is critical to a SWMP.

   Base mapping and planimetric data are typically generated at the county or city level. This data may be produced in-house or the project may be contracted out to a consulting firm. This data often includes tax parcels, zoning districts, land use, parks, open water, right-of-ways, railroads, and building footprints. Street centerline data layers of varying qualities can be obtained from a number of vendors. The market is relatively competitive, and prices will vary with quality of the data. Relevant vendors that provide this kind of spatial data on a regional and national scale include: NAVTECH <www.navtech.com>, GDT <www.geographic.com>, and TeleAtlas <www.teleatlas.com>.

   Other spatial data layers can be obtained through the Internet from various government sources. Municipal boundaries and similar layers can be obtained in digital format through the U.S. Census Bureau <www.census.gov>. Floodplains can be obtained through the FEMA Web site <www.fema.com>.

   Regardless of the source of the data, each data layer used to build the storm water inventory should be consistent with, or be modified to match, the Virginia Base Mapping Project orthophotography. This is vital for data consistency across the state and it facilitates data sharing across jurisdictional boundaries. The digital orthophotography provides an excellent base data layer on which to display the storm water drainage system and create map books for field use.

4. Data Conflation Options (integrated with VBMP digital orthos)

   Data conflation is a process by which two digital data layers, usually of the same area at different points in time, or two different data layers of the same area, are geographically "corrected" through geometrical and rotational transformations so that the different layers can be overlaid on one another. Also called "rubber-sheeting," this process allows a technician to adjust the coordinates of all features on a data layer to provide a more accurate match between known locations and a few data points within the base data set. A good base layer to use for data conflation is the VBMP orthophotos since many features can be seen or interpreted. The need and processes for conflation varies between sets of data, users, and feature types. Any dataset that is updated independently by different departments can be consolidated through conflation. Within

most local governments, individual departments are responsible for maintaining specific datasets within their expertise; therefore, conflation is not often necessary. Often, reprojecting the data into a different coordinate system will take care of the misalignment of different data sets. Most industry-standard GIS software has the ability to perform data conflation.

Most industry-standard GIS software has the ability to perform data conflation. In the case of a storm water feature inventory, is important to either capture the storm water features in the same projection as the VBMP orthophotography or reproject it later to match the orthophotos. This ensures that when the locations are converted into a GIS data layer, the features will appear in the correct location on top of the orthophotos.

5. GUI / programming options

There are many options for developers of a GIS-based SWMP. Three avenues within this development track are:

- Off-the-shelf GIS desktop application that can be customized to the user's needs
- Existing commercial SWMP applications.
- Hiring a consultant to develop a custom system from scratch.

Using a standard GIS software package often requires a significant amount of training and customization. Whereas the initial cost may be lower, the time invested in learning these solutions may generally increase the overall expense of implementation. However, standard GIS software packages deliver more robust data integration, analysis, and cartographic capabilities than do other specialized commercial applications. They have a greater user support infrastructure that allows users to overcome problems quickly. Options for using an existing, industry-standard GIS software application that can be customized for a storm water inventory system include those listed in the following table:

Standard GIS Software Vendors:

Vendor	Software	Web Address
ESRI	ArcView 3.x	http://www.esri.com
ESRI	ArcGIS 8.x	http://www.esri.com
MapInfo	Professional 7.0	http://www.mapinfo.com
Intergraph	GeoMedia 5.0	http://www.intergraph.com/gis
Autodesk	Map 5.0	http://www.autodesk.com

There are an increasing number of vendors developing and implementing infrastructure management software, including components for storm water inventory and/or management functions. These products may often cost more than standard GIS solutions because of the customization that is required to fit the application into the agency's business practices and/or connect to its data source. The advantage is that a tailored application provides just the functionality that is needed, decreasing the overall application overhead common to industry-standard GIS software. Options for using an existing, commercial storm water inventory system include those listed in the following table:

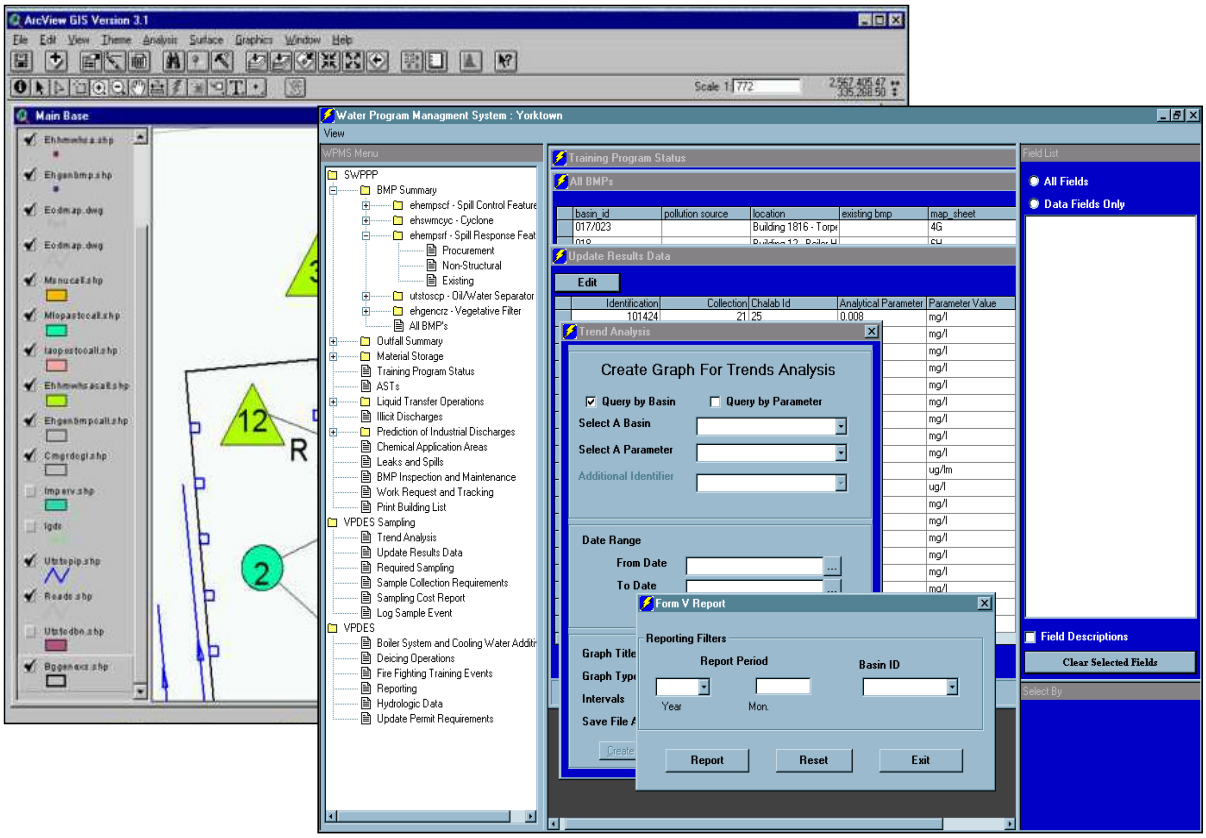
Commercial Software:

Vendor	Product	Web Address
Azteca	CityWorks	http://www.azteca.com
CarteGraph	WATERview	http://www.cartegraph.com
Hansen	Hansen 7.5	http://www.hansen.com
GBA Master Series	GBA Storm Master	http://www.gbamasterseries.com/

The final option for developing and implementing a GIS-based SWMP is to contract with a consultant. This option makes certain that a product will fulfill an agency's requirements. A consultant will be able to develop an application that works with the wide range of hardware and software that are currently in use within local governments within Virginia. Also, training and follow-up user support is often provided at a much more substantial level than with other options.

There are several options for functionality that should be considered in a GIS-based SWMP application. While not all municipalities have the same needs, the following list presents a few of the possibilities:

- Viewing and querying storm water drainage features
- Generating work orders
- Estimating costs
- Generating reports
- Running hydrologic models
    - Predicting storm runoff areas
    - Predicting 100- or 500-year flood zones and who will be affected
    - Watershed models
- Create an asset inventory for GASB 34
- Aid in master planning and capital improvement project (CIP) requirements
- Ability to produce maps on demand at certain scales
- Maintain photographs of the storm water inventory
- Maintain historical data on past flood events, illegal tie-ins, etc.
- NPDES permitting and other environmental impacts



Custom interface for adding BMPs to storm management application

6. Internet Functionality and options

The Internet has proven itself as a viable solution for local governments to centralize the maintenance and management of services and data. As more local governments are implementing Web-based solutions, they are finding that the Internet requires them to change the nature of an application or its usefulness. Through the flexibility of an Internet solution, software can be easily updated, and users gain greater accessibility to the applications and information they need for their specific tasks through simple, user-friendly interfaces.

If a local government so chooses, they can deploy a Web GIS application to allow citizens of their community to view maps of the storm water drainage system or results of modeling runs (such as 500-year flood zone, priority neighborhoods for new infrastructure, etc.). GIS software vendors have products that can be customized in-house or by a consultant to provide Web GIS applications on the Internet, over an intranet or via wireless network. The table below shows GIS vendors and their Internet mapping solutions.

GIS Internet Solutions

Vendor	Internet Software	Web Address
ESRI	ArcIMS	http://www.esri.com/software/arcims
MapInfo	MapXtreme, MapX	http://www.mapinfo.com
Intergraph	GeoMedia WebMap	http://www.intergraph.com/gis/gmwm

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Autodesk	MapGuide	http://www.autodesk.com

7. Technical Requirements

Minimum Technical Requirements
At its most basic level, a SWMP can be used on a single, stand-alone workstation. This workstation would have a hard drive that stores all of the spatial data layers, as well as the GIS software package or application itself. A typical workstation running off-the-shelf software should have the following minimum specifications:

Processor:	Pentium 3; 450 MHz
RAM:	128MB SDRAM at 133MHz
Hard Disk:	20GB (min.)
Monitor 1:	19"
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD drive
Modem:	56K
OS:	Windows 2000/NT/XP
Office:	Windows 2000 Professional
Printer:	8x11 office-grade color printer

Optimum Technical Requirements:
A more complex SWMP may require multiple components, including servers, desktop workstations, ruggedized laptops, or handheld devices. The scale at which the system is implemented, thus the technical needs, is dependent on the number of daily GIS users as well as the number of data collectors. For either a desktop or a Web-based application, the system should rely on a fairly robust server computer and high-end workstations. Some examples specifications of the necessary equipment are listed below:

Server

Processor:	Min. 2x Processors, 1.7 GHz, 512K cache
RAM:	Min. 2x 512MB RIMMS
Hard Disk:	Min. 2x 80GB +RAID
Monitor 1:	19"
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD drive
Modem:	56K
Network Card:	10/100 mbps

Workstation

Processor:	Pentium 4, 1.5 GHz
RAM:	512MB SDRAM at 133MHz
Hard Disk:	20GB (min.)
Monitor 1:	19”
Monitor 2:	17”
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD-RW drive
Modem:	56K
Network Card:	10/100 mbps
OS:	Windows 2000/NT/XP

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Office: Windows 2000 Professional

Other Components

Printer: 8x11 office-grade color printer and 8x11 production b/w printer
Plotter: HP DesignJet 1055CM
Tape Backup: Tape Library Server
UPS: APC 1400 (or other similar)
Scanner: 11x17
Handheld: Compaq IPAQ
Network: T1

8. Administrative/Management Requirements

At the beginning of the project, the assigned project manager from the particular municipality should consider completing some, if not all of the following tasks that relate to the administrative requirements of a SWMP:

- Determine, with or without the assistance of a consultant hired to develop the system, the preliminary vision and goals of the project.
- Coordinate an initial meeting with the stakeholders (i.e. the Board of Supervisors, City Council, public works department, local/state environmental agencies, etc.) where the vision and goals of the project are expressed and the background of GIS technology is described, if needed.
- Coordinate with other municipal agencies for data sharing provisions.
- Determine a mechanism of communication to keep the decision-makers aware of the progress of the project.
- Develop a basic understanding of the available precedents in the region/state and research the available technologies that can be applied to the project.

Upon project completion, a basic SWMP will require very little administrative support. Administrative tasks may include loading or upgrading new versions of the software or patches, providing for constant data flow from the source database, and maintaining yearly support contracts on the hardware and software. However, once the system becomes distributed as an enterprise solution to many users throughout a department or deployed on the Internet, there are various other management requirements that need to be fulfilled on a weekly or monthly basis.

At the point where the system grows beyond single desktop users, a devoted administrator or system manager needs to be established. This is essential for the following reasons:

- The system will now be interfacing with other technology systems already in place. Therefore, someone needs to maintain contact with the technology personnel that maintain these systems.
- The manager needs to put into place training schedules to maintain user knowledge of the system.
- Funding will undoubtedly be required to either maintain the system long-term, or continue to expand the system, which requires funding research and applications for grants.

9. Cost – Cost/Benefit

Hardware	**Average Unit Cost**
Minimum Workstation	$2,000
Optimum Workstation	$3,200
Laptop	$2,400
Web/FTP Server	$8,500
Database Server	$12,000
Data Warehouse Server	$18,000
Backup Server	$5,800
Printer (8x11 color)	$700
Printer (8x11 b/w production)	$2,000
Plotter	$12,000
Tape Library	$5,000
UPS (Universal Power Supply)	$700
Scanner	$1,500
Handheld	$300-$700

Software (all prices included license)	**Typical Unit Cost**
Standard GIS desktop software	$700-$10,000
Customized desktop vendor solution	$5,000-$15,000
Web-based vendor application	$15,000-$25,000
Customized web-based vendor solution	$20,000-$60,000

Miscellaneous	**Typical Unit Cost**
Training – focused vendor training (per person)	$700-$1,000
Training – general GIS	$700-$1,200
Licensing – desktop	$100-$500
Licensing – webapp (1st CPU)	$7,500-$12,000
Maintenance (per year)	$8,000-$15,000

10. Standards / Guidelines Summary
    - *Refer to the VBMP Reference Book topic on Storm Water Drainage Inventory for guidelines on conducting an inventory.*
    - A GIS-based SWMP application should be built so that non-technical personnel can be trained to use the system.
    - Acquire input from all departments who will be involved in funding and/or utilizing the SWMP application before proceeding with the application design.
    - Verify that the analysis output and reports from the GIS application meet the requirements for any permitting programs (such as NPDES or VPDES).
    - Develop a detailed Quality Assurance/Quality Control (QA/QC) procedure for reviewing the accuracy of the GIS data and its attributes.
    - Maintain data in the VBMP standard coordinate system (Virginia State Plane, NAD 83, Survey Feet).
    - Create metadata (standard information about GIS data) for each data layer. Metadata tracks the date, origin, coordinate system, and other such information for data layers.

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11. Startup Procedures/Steps

There should be a minimum of eight steps involved with developing a GIS-based SWMP application, after funding is in place to support the project. The steps can be performed in-house or by a consulting team.

The first task is to complete a detailed Needs Assessment. This process gathers information regarding existing operational procedures, hardware and software, GIS data, and personnel needs. It should include interviews of key individuals throughout the local government agency and other related government departments to obtain a comprehensive view of the agency's operations, and where GIS might improve them. Basic GIS concepts should be discussed and illustrated to those interviewees that have little prior understanding of GIS. A comprehensive Needs Assessment should then be compiled from the results of the interviews. This document explains the various requirements for a SWMP system in the following areas: personnel needs, spatial data development needs, applicable spatial analysis techniques, basic system requirements, including preliminary, general hardware and software recommendations, and training needs.

The second task is to develop a functional requirements document for the proposed system. This document should describe, as completely as possible, all of the technology and functionality that is to be included in the SWMP application. This document is used by the local government agency, or its consultant, as the blueprint for the GIS application or system. It should include:

- Hardware specifications
- Software purchases
- Detailed descriptions of work-flow, and examples of the graphic user interfaces
- Describe each tool that is part of that graphic user interface, and its functionality
- Describe how data would flow between the different databases and data warehouses, if applicable
- Describe the redundant security measures that will be put in place to make certain of data integrity and confidentiality, when applicable
- Analytical techniques that the application/system provides the user for queries and analysis
- Describe each of the potential products (reports, maps, charts, summary tables) that the user will be able to generate within the system

The third task should be to compile or develop storm water drainage spatial data that can be used by the evolving water meter location inventory system. Data can be gathered from a number of online sources, as well as county/city departments. The data layers gathered and maintained should match at least the minimum list provided in Section 1 of this document and can be acquired through the methods described in Section 3 of this document.

On completion and acceptance of the functional requirements document and the development of the spatial and attribute data, the system development and test phase can begin. During this time, the application will be customized as it was outlined in the functional requirements phase. The local government agency should require periodic reviews of the application at particular milestones, such as 50% and 75% completion. This will make certain that problems with the application will be recognized early in the development process, and that the local government agency remains a part of the development process throughout the project timeline.

When the system is nearing 100% completion, it should be installed and tested in the environment in which it will ultimately be used. This allows the users to test the system alongside the application developers, and determine any system integration problems that might arise. It also gives the developers the opportunity to test the application's functionality in a real-world situation. This testing process should be as comprehensive as possible. Each process detailed within the functional requirements should be tested and evaluated at this point.

User training commences once the application reaches 100% completion and is fully documented. Different levels of tutorials and system documentation should be developed depending on the hierarchy of users. Time should be spent at this stage of the project with each potential user of the system to make certain that the proper education occurs. Training should be done through lessons that use real-life examples of system application. This strategy greatly enhances users' ability to apply the functionality to their jobs.

The next phase of the project should include a document that describes a future plan for wider system development. This document accomplishes two goals. The future plan gives the local government agency ideas on how the system might grow to assist other facets of its business practices. Secondly, it provides the agency with a ready-made grant proposal for applying for potential funding sources.

The final phase of a successful implementation of a GIS-based SWMP application is ongoing technical support. The local government agency should always include this contingency within its cost estimates of a project for a minimum of three months after a system has been put into place. No matter how effective an application appears, problems and system changes inevitably impact the functionality of a system.

12. Estimated time line and/or implementation (stand alone) schedule

Phase	Approximate Duration
RFP/Contract process (construction, posting, proposal acceptance, review, award of contract)	4 months - 1 year
Needs Assessment	2 months
Functional Requirements	1-2 months
Data Development	6-12 months
System Development and Testing	2-4 months
Installation and Testing	1 month
User Training	½ month
Plan for Future Development	½ month
Ongoing Support	3 months

13. Best Practice Examples in Virginia

City of Hampton
Public Works
22 Lincoln Street, 4th Floor
Hampton, VA 23669
757-727-8311
www.hampton.va.us/publicworks/engineering_services_gis_services.html

Prince William County
Public Works
4361 Ridgewood Center Drive
Prince William, VA 22192
703-792-6666
www.pwcgov.org/pworks/env_services/swmgmt.htm
http://www.epa.gov/OWOW/watershed/Proceed/pasquel2.html